HUNTSMAN

Enriching lives through innovation

Clay Control

IN DRILLING AND COMPLETION

Clay Control Basics

Clay minerals, generally crystalline in nature, typically have a flaky structure. Clay flakes are made up of a number of crystal platelets stacked face-to-face in layers held in place by weak attractive forces. Water invasion of clay deposits causes swelling, a process by which water molecules are adsorbed onto crystal surfaces and drawn by osmosis between the layers of clay flakes, forcing them apart.

Shale is a type of sedimentary rock composed chiefly of silt and clay. There are many different types — bituminous shale, oil shale and gas shale — all of which are important sources of fossil hydrocarbons. Clay swelling in shale formations during drilling or well completion can have a tremendously adverse impact on oil and gas operations.

Traditionally, preventing clay swelling in oilfield operations by aqueous liquids has been achieved using large concentrations of inorganic salts, mainly potassium chloride (KCl). However, effective clay control requires high concentrations, which can be difficult to apply.

Current methods of clay control involve both polymers and ammonium compounds. Polymers stabilize clays by reducing the rate of water penetration into the shale, while amines and ammonium compounds inhibit swelling by chemical means.

Amines/quaternary compounds inhibit swelling by changing the ionic strength and the transport behavior of fluids into clays, thus preventing clay platelets from moving further apart.

In field operations, inhibitors are often used in conjunction with minimal concentrations of KCl to provide maximum clay control. Fluid design compatible with formation minerals and other components under site-specific work conditions is a key element of success.

Huntsman's leadership position comes from its range of technologies, world-scale integrated manufacturing capabilities, and global distribution network.

Huntsman Clay Control Chemicals

By use of proper concentration of glycol ether, solvent and KCl, the cloud point of a clay control fluid can be adjusted to a particular downhole environment. Amine compounds are often more effective when applied as ammonium salts.

Product	Chemistry	Mode of Action	Lubricant	Applications
JEFFADD® OFS 124 **JEFFADD® OFS 125** **JEFFADD® OFS 126**	Ether polyamines	• Binds clay platelets • Partial or total KCl replacement	No	• Inhibitor for dispersed clays • Effective over Wide pH range • Also functions as anti balling agent • Effective in high pH (> 10) muds
JEFFADD® OFS 127 **JEFFADD® OFS 781**	Etheramine	• Shale inhibitor performance booster	No	• Add 5 - 20% to OFS 124-125 inhibitors

We provide innovative solutions to some of the oilfield industry's biggest challenges, like shale inhibition and corrosion control, to help maximize production and reduce costs.

Amine/Quaternary Shale Inhibitors

Several laboratory methods of evaluating shale inhibitor efficiency are being used industry wide. Huntsman clay control agents and their acetate salts have been rigorously tested in accordance with published protocols.

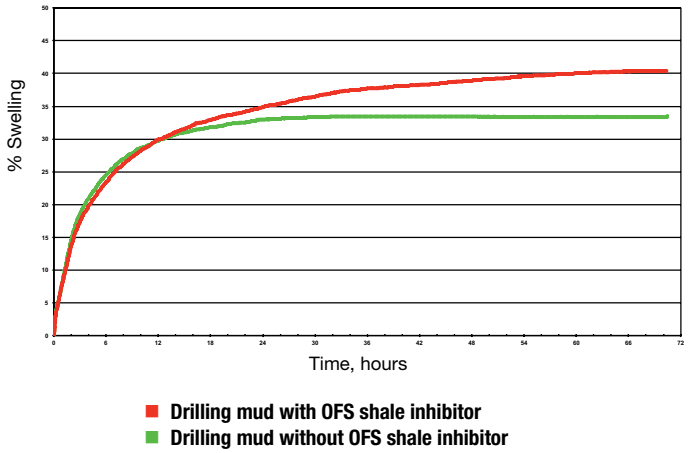
- **Capillary Suction Test (CST):** Often used as a preliminary screening method. Slurries of bentonite clay, silica flower and inhibitor in water were filtered through a specialty paper filter while the instrument measured the speed of filtration. Faster filtrate flow indicates less swelling and improved performance.

- **Dispersion Test (Hot Rolling):** Shale pieces between 4.75 and 6.7 mm size were tumbled in water base drilling mud formulations for 16 hours at 90°C (194°F) in a rolling oven and screened through a 0.85 mm sieve. Surviving chips were washed and dried. Higher retained weights of shale indicate improved shale stabilization.

Different clays may produce different results.

Dynamic Linear Swelling:

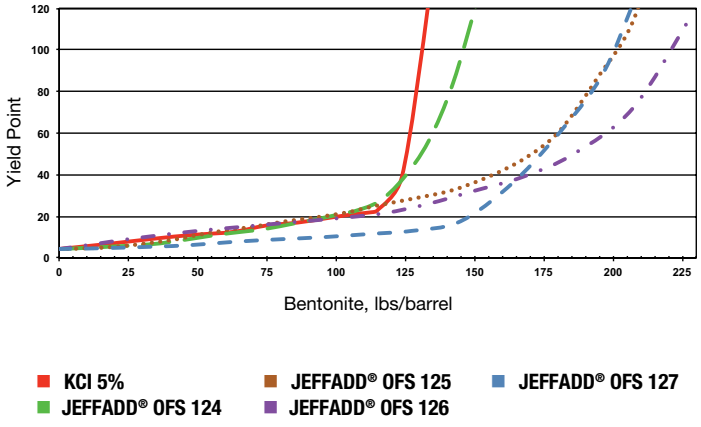
The OFITE Swellmeter measures clay swelling at wellbore conditions. Compressed pills of bentonite were submerged in a drilling mud at high temperature and the amount of vertical swelling recorded over time. Less swelling indicates improved clay inhibitor performance.



Testing at 70°C, bentonite pill stopped swelling after 30 hours in mud formulated with OFS shale inhibitor while continued swelling was observed with a common reference shale control agent.

Mud Rheology:

Bentonite was incrementally added to water base drilling muds (3% inhibitor) until the muds became too thick to measure their viscosities. The ability to absorb more bentonite indicates improved clay inhibitor performance. Baselines representing the uninhibited system and 5% KCl are added for reference.

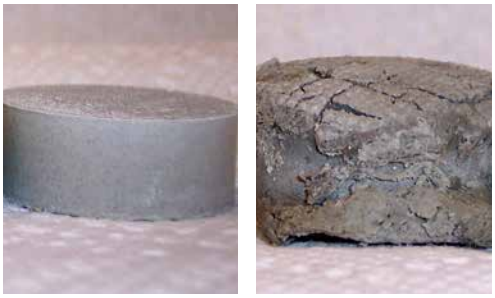


Water base drilling mud after incremental addition of bentonite. Viscosity measured on Fann 35 at 3 rpm. A mixture of sodium hydrogen carbonate and sodium carbonate was used to adjust pH to 9.

Clay Inhibitor	Capillary Suction Test Efficiency vs. 5% KCl*, %	Dispersion Test, Clay Retained,** % pH > 10	Dispersion Test, Clay Retained,** % pH > 10
NO INHIBITOR	>1000	33	11
JEFFADD® OFS 124	9.0	50	< 46
JEFFADD® OFS 125	-3.0	85	49
JEFFADD® OFS 126	3.6	84	73
JEFFADD® OFS 127	9.4	97	91
JEFFADD® OFS 781	0.6	94	67

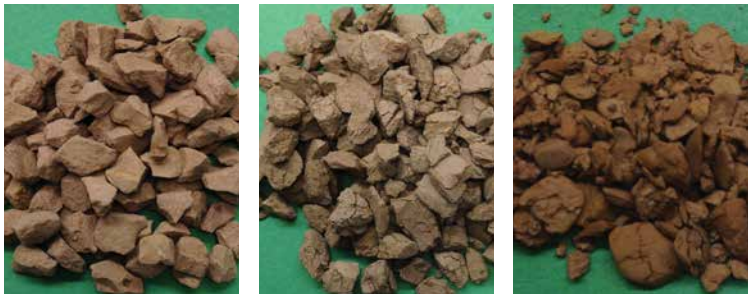
* Negative number indicates performance better than 5% KCl, amines tested at 0.5% concentration.
**Tested on Khvalynsky brown "chocolate" clay from Volgograd region in Russia, 3% shale inhibitor. Different clays may produce different results.

Bentonite Pills

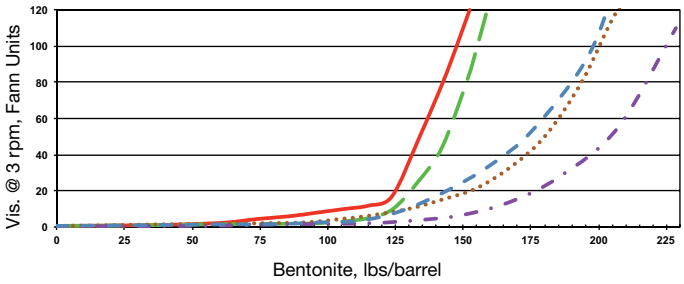


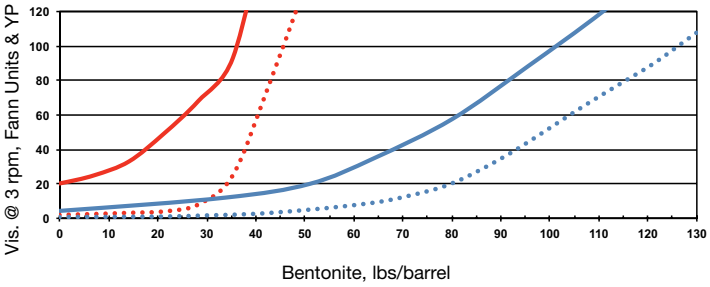
Unexposed **Swollen**

Shale Chips (4.75mm to 6.7mm)



Unexposed **Well Inhibited** **Poorly Inhibited**





■ **KCl 5%** ■ **JEFFADD® OFS 125** ■ **JEFFADD® OFS 127**
■ **JEFFADD® OFS 124** ■ **JEFFADD® OFS 126**

■ **No inhibitor YP** ■ **JEFFADD® OFS 127**
●● **No inhibitor YP Vis. 3 rpm** ●● **JEFFADD® OFS 127 Vis. 3 rpm**

Calculated Yield Point (lbs/100ft²) of water base drilling mud after incremental addition of bentonite at pH 9.

Viscosity and Yield Point (YP) of water base mud at pH 13 (NaOH). Comparing to pH 9 experiments it is clear that high pH has a detrimental effect on the mud rheology.

About Huntsman

Huntsman Corporation is a publicly traded global manufacturer and marketer of differentiated and specialty chemicals with 2019 revenues of approximately $7 billion. Our chemical products number in the thousands and are sold worldwide to manufacturers serving a broad and diverse range of consumer and industrial end markets. We operate more than 70 manufacturing, R&D and operations facilities in approximately 30 countries and employ approximately 9,000 associates within our four distinct business divisions. For more information about Huntsman, please visit the company's website at www.huntsman.com.

Huntsman Performance Products

Performance Products brings together innovation and world-leading process technologies to produce components used to formulate products that enhance people's lives. Our leading global positions in the manufacture and sale of amines, maleic anhydride and carbonates enable us to serve diverse consumer and industrial end markets, including energy, automotive and transportation, coatings and adhesives, construction and infrastructure, electronics, and industrial manufacturing. With 10 manufacturing facilities in North America, Europe, the Middle East and Asia, we produce and sell over 350 products to over 900 global customers, and provide extensive pre- and post-sales technical service support. The division had 2020 revenues of USD 1 billion.

www.huntsman.com/pp

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